Extended Filter Bank Options for the JPEG2000 Image Coding Standard

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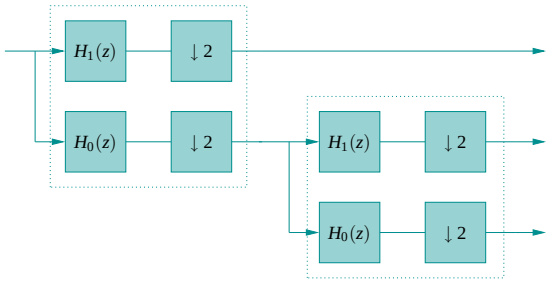
Aside from the obvious commercial and consumer applications, image compression plays an important role in the handling of a wide variety of scientific and engineering data, including, for example, multi-spectral satellite images and the results of large hydrodynamic simulations. Considerable progress has been made in this very active area of research since the publication of the original JPEG standard in 1996. Based on many of these improvements, the *Part 1* baseline [1], and *Part 2* extensions [2] of the JPEG2000 standard have recently been published. Our primary involvement in the standards process (we are currently working on *Part 10* extensions for support of 3D and floating point scientific data) is directed at incorporating features and flexibility for scientific data coding applications, which is not a priority for many other participants.

The existing JPEG standard is based on the Discrete Cosine Transform (DCT), which is applied independently to 8×8 pixel blocks of the image to be coded. This transform, a relative of the Discrete Fourier Transform, shifts most of the image "energy" to the lowest frequency coefficients in an 8×8 block, allowing a reduction in the number of bits required to represent the block by representing the higher frequency coefficients at lower accuracy. While very good quality image reconstruction can be obtained at high bit rates (low compression ratios), quality is quite poor at low bit rates, and blocking artifacts (visible block boundaries) resulting from independent coding of the 8×8 blocks can be very objectionable.

The JPEG2000 standard [5] replaces the DCT with a Discrete Wavelet Transform (DWT) [4] applied to the full image, thereby avoiding these blocking artifacts. The multiresolution structure of the DWT representation supports a number of additional advantages, including the ability to order the coded bitstream so that the decoder receives a low resolution approximation to the image, followed by a description of detail at progressively higher resolutions. While efficient quantization (representing each floating point value by the nearest value in an indexed set) and entropy coding (lossless compression similar to that performed by the popular *zip* and *gzip* programs) is important in obtaining good performance, the wavelet transform plays a crucial role in providing appropriately decorrelated and "energy compacted" coefficients to these stages.



A one-dimensional two-level wavelet decomposition constructed as a cascade of three two-channel filter banks. A two-dimensional decomposition is obtained by applying the one-dimensional decomposition to the image rows and columns.

The fundamental module from which the DWT is composed is a *perfect reconstruction two-channel filter bank*, which applies a lowpass filter (which attenuates high frequencies) to one channel, and a highpass filter (which attenuates low frequencies) to the other [6]. These modules are cascaded on the lowpass channel, the output of which is fed into the next module, while the output of the highpass channel is a representation of one level of the detail information which is added to create representations of increasing resolution. The decorrelating properties of a particular DWT are chosen by designing the lowpass and highpass filters in the filter bank module. While Part 1 of the JPEG2000 standard provides only two fixed filter banks, designed for good performance over a wide range of image types, the extensions in Part 2 of the standard allow the use of filter banks

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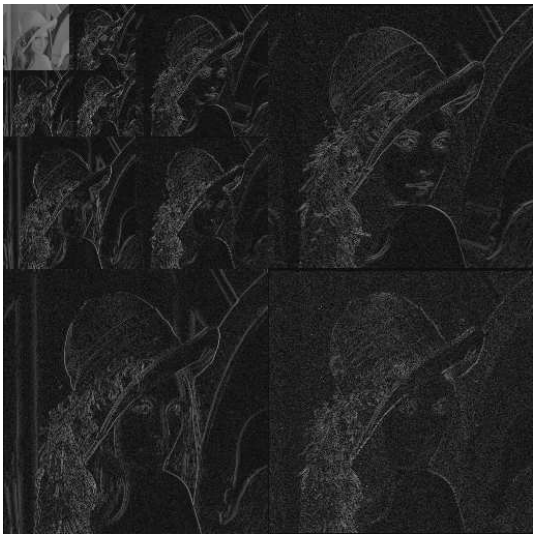
The "Lena" standard image.



A three-level wavelet transform of the "Lena" standard image. The low resolution representation is at the top left, and the other blocks represent detail, of progressively higher resolution towards the bottom right, that is necessary to reconstruct the original image.

designed for specific applications (for example, multi-spectral satellite imagery or synthetic aperture radar data). The original draft of Part 2 excluded support for a large class of filter banks, which were believed to be incompatible with the framework of the baseline standard. Our research in this area lead to the development of an effective mechanism for supporting this class of filter banks. This technical solution has been included in Part 2 of the JPEG2000 standard [2], and two papers (preliminary versions of which [3, 7] were presented at *VCIP 2003*) describing the associated theoretical work are currently in preparation for submission to the relevant IEEE transactions.

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